

innate structure of the information conveyed is digital the transmission may be viewed as such. In this context, some prefer to view a digital modulator and RF. transmitter as a RF. modem.

To accommodate emerging multi-media applications involving digital voice, digital text and digital imagery/video, these bandwidth efficient digital implementations are necessary to exploit the very limited occupied bandwidths proposed with either 5 or 6.25 KHz channels. Such multi-media applications could easily necessitate the use of 64-QAM which could provide for information transfer rates of 24-30 kb/s in the FCC narrowband channels.

But as compared to today's digital practice how much of an improvement in bandwidth efficient technology is necessary? We believe quite a lot. Consider for example, if the APCO Project 25's proposed channel format becomes a final standard, a gross channel rate of 9.6 kb/s is required. Thus, in terms of bandwidth efficiency (assuming a 9.6 kb/s gross channel data rate), at a 5.0 KHz occupied bandwidth a bandwidth efficiency of 1.92 is achieved increasing to 2.4 b/s as the authorized occupied bandwidth is reduced to 4.0 KHz. But the APCO plan is to employ a variant of 4-QAM, and best case it will fit within the 5.0 KHz emission mask, at 4.8 KHz occupancy it is outside of the 4.0 KHz mask. The solution is, of course, technical.

In the mid 1980's we were advocating the use of 7.5 KHz channel bandwidth for every bandwidth efficient digital cellular communications system. Then, it appeared that given the state of available technology the highest cost effective information rate sustainable in a 6.0 KHz information bandwidth subsumed in a 7.5 KHz channel was approximately 10 kb/s. This scheme was predicated on a bandwidth efficiency of 1.7 b/s/Hz. Our concept at the time ignored the signaling overhead necessary to effect

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certain system management functions and instead concentrated on very robust half rate error detection and correction (EDAC) coding. At that time, circa 1986 these proposals were met with widespread opposition. Today, in 1993 similar and even more aggressive operational modalities are becoming commonplace.

The question then arises: what happened between 1986 and the present? In a nut shell, the advances have been in the area of digital signal processing technologies. What was allegedly not economically implementable six or seven years ago in monolithic or hybrid technology is now easily implemented through dramatically more powerful DSP's. In fact, with current price versus performance ratios of commercial DSP's, one doubts if current proposal, are pushing the development of the art. Today with DSP technology in the 100's of MIPS range little is difficult or impossible. But for that which pushes the art, we anticipate DSP's operating in the 1000's of MIPS range being available for integration in hand held/portable sets within the next three (3) years.

Today, at the time of this writing in JULY 1993, anyone may purchase equipment that operates at a gross data rate of 9.6 kb/s in a 12.5 KHz channel vis-a-vis ASTRO which is Motorola's advanced narrowband digital communications (ANDC) implementation. If we assume that the occupied bandwidth is 20 percent of the channel bandwidth, ASTRO type technology has a current bandwidth efficiency of .96 b/s/Hz.

If ANDC is compared to current, 12 kb/s digital voice systems that have been in use since the mid 1970's(which some insist on referring to as analog) which operates in a 25 KHz channel, ANDC's current bandwidth efficiency of .96 b/s/Hz represents almost a 100% improvement as compared to the approximate .6 b/s/Hz bandwidth efficiency of the 12 kb/s systems. This comparison of course neglects the fact that at 9.6 kb/s

ANDC provides for embedded signaling that 12 kb/s CVSD systems can not provide in a 25 KHz channel.

Additionally, in the public safety community a standards effort is in process under the Associated Public Safety Officers (APCO) Project 25 umbrella. The APCO 25 process will have as its work product a "standard" for interoperable, advanced narrowband digital public safety communications. Compliant ANDC equipment will initially operate in a 12.5 KHz channel, employing a gross channel data rate of 9.6 kb/s. Voice digitization will be effected at 4.2 kb/s through the use of a vocoder technique referred to as Improved Multi-Band Excitation (IMBE). Embedded encryption, such as DES, and signaling is proposed along with a modest quantify of EDAC resulting in a gross channel rate of 9.6 kb/s. For the initial implementation using compatible Quadrature differential phase shift keying (QDPSK) RF. modulation the system will operate at 12.5 KHz channel spacing. Later, migrating toward 6.25 KHz channel spacing, the compatible architecture is configured to provide a graceful conversion/migration to 6.25 or even 5 KHz channels. This migration may be complicated by the final authorized bandwidth provisions of the refarming NPRM along with the associated technical parameters related to emission shape factor and channel spacing.

The bottom line is that effective use of narrowband channels requires the use of bandwidth efficient techniques that demand more power than their inefficient counterparts. To support the demands of the user population for multi-media information transport, very high bandwidth efficient techniques are mandated.

In addition, we agree with many that see a need for feed forward automatic frequency control techniques and DSP controlled power amplifiers to maintain system integrity.

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But most important of all, we believe is the absolute acceptance and use of linear system architecture's. The pioneering work performed by McGeehan and Bateman, from the University of Bristol in the UK over the last decade, scratches but the surface of the potential of linear transmission. It is in this final analysis that linearizing our heretofore corrupted wireless environment will we be able to fully exploit the works of Shannon and maximize the use of our spectrum resource.